Contents lists available at ScienceDirect

International Journal of Child-Computer Interaction

Patterns in informal and non-formal science learning activities for children–A Europe-wide survey study

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ARTICLE INFO

ABSTRACT

There is a growing number of informal and non-formal learning activities worldwide related to STEM (Science, Technology, Engineering, Mathematics) curricular subject areas—particularly those involving coding and making. To better understand the general aim and content of such activities, we conducted a survey addressing highly experienced instructional designers and instructors of informal and non-formal science learning activities in nine European countries (N = 128). The goal of this paper is to investigate the relation between the gender of the activity leader experts, the target audience, the covered curricular subjects, the main goal, and the place of the activity. The results show that the gender and age of the participants are related to the covered curricular subjects and to the goal of the activity, and that the place of the activity is associated with all of the investigated dimensions. We introduce the patterns we identified that describe typical goals and the covered curricular subjects in relation to the participants' gender and age along with patterns between the activity leader experts' gender, the covered curricular subjects, and the main goal of the activity, as well as relationships between the studied dimensions and the place of the activity. Furthermore, we discuss the best practices and the bottlenecks of the activities, as well as detailed study findings regarding the revealed patterns, in addition to their implications and value for the informal and non-formal learning communities.

1. Introduction

Nowadays, the contribution of informal and non-formal learning activities to lifelong learning is widely acknowledged, with the concepts of ubiquitous, everyday, and intuitive learning drawing the attention of both educational institutions and society (e.g. [1,2]). Despite this increasing interest, informal and non-formal activities are still underresearched, with most of their design decisions relying on the intuition of the expert or the instructional designer.

Informal and non-formal science learning activities for children occur in different places and contexts, such as museums, libraries, computer clubs, Fab Labs (i.e., digital fabrication laboratories), youth centers, conferences, or universities (e.g. [3–15]).

Some studies have reported on entirely voluntary activities taking place in youth centers, museums, libraries, or computer clubs, whereas other studies have explored activities organized as elective, after-school classes, as extra-curricular activities, or even as summer camps (e.g. [6,8,10]). From the wide range of places and contexts, much attention has been given to activities taking place in a more traditional environment (i.e., museums, zoos, exhibitions, etc.). However, the links and contributions of the emerging innovative, creative learning and digital fabrication spaces to science education are still underexplored. In these spaces, the activities are constituted from diverse coding and making activities, integrating playfulness and creativity, i.e., combining fun and enjoyment as dominant elements of creating something new. With coding, we refer here to computer programming on different levels, ranging from its simplest form of computer language being taught, e.g., in primary education, to its more complex forms taught in secondary education. Making refers here to the creative production of physical artifacts.

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Although most of the informal and non-formal activities are focused on STEM (Science Technology, Engineering, Mathematics), we have seen a wide diversity of design decisions with no clear rationale for how to relate the expected learning outcomes to the way in which the activity is designed [16,17]. In a study exploring youths' attitudes toward science from after-school programs, making and scientific argumentation activities were shown to give youth the opportunity to contextualize STEM concepts and broaden their future career options [18]. Two of the most important elements emphasized in the literature [19] are the age and gender of the participants, but there are still no clear guidelines on how these elements can be addressed during the design of the activity. There is also a lack of studies on the dynamics and relationships between the gender of the activity leader experts, the target audience (age and gender), the covered curricular subjects, the main goal, and the place of the activity, nor has there been sufficient research on the best practices and difficulties associated with these activities. This study aims to fill these research gaps. The novelty of our study is also its broad coverage in terms of content and countries involved; our research addresses the topic in an overarching way at a European level. Gaining insight into these dynamics and relationships not only increases our understanding of the ongoing non-formal and informal science learning activities in general, but it also provides a good starting point to design future activities in a more conscious way; for example, to fill existing research gaps, to increase girls' involvement, or to design activities that better suit the anticipated audience.

To address the topic, we conducted a survey study focusing on coding, making, and playful activities in nine European countries (Austria, Finland, Greece, Malta, the Netherlands, Norway, Spain, Sweden, and the UK). In this paper, we examine responses from 128 highly experienced instructional designers and instructors of informal and non-formal science learning activities (i.e., experts) and discuss how our findings can inform future science learning activities as well as advance research in the area of informal and non-formal science learning activities for children.

2. Related work

For our conceptualization of formal, informal and non-formal learning, we draw upon definitions from The Council of Europe,[1] and from definitions provided by Eshach [20]. An overview of the main differences between the three terms based on the definitions of the Council of Europe and Eshach [20] is presented in Table 1.

In contrast to formal learning activities, extracurricular – thus informal and non-formal – activities have been associated with an increased level of engagement and intrinsic motivation among adolescents [21]. Intrinsic motivation, therefore, is considered to have a strong effect on learning in general and to play a key role in the case of informal and non-formal science learning activities. In addition, engagement is generally categorized into three facets: behavioral, emotional, and cognitive engagement [22]. Often, in educational studies, each of these facets is investigated. Based on Bandura's social cognitive theory [23], learners' affective and cognitive engagement is constructed through continuous interaction with the learning environment. Additionally, an activity is optimally engaging when the requisite level of skills and challenges are met. When this occurs, a higher quality of perceived engagement, intrinsic motivation, mood, and self-esteem is present [24].

With the bulk of the literature reporting on specific cases and design research studies, there are only a few studies that have examined the content and main goal of informal and non-formal learning activities in STEM at an overarching, comprehensive level; yet, these studies lack the specific focus of our study. The study by Falk and colleagues [2] examined UK science education by taking a systemic perspective. They examined science learning as a whole by including both formal and non-formal settings, and they sought to collect information regarding, among other aspects, the educational goals and target audiences of such activities. Their findings suggest some consistency in the distribution of audiences across sectors: a predominant focus on children and youth (age range of 5–19), followed by adult audiences. Regarding the educational goals of such activities, the most frequently mentioned were to *make science enjoyable and interesting* (91%) and to *inspire a general interest in and engagement with science* (89%), whereas the least frequently mentioned were *preparing participants for further science education or careers* (27%), *encouraging further learning in non-science subjects* (23%) and *preparing participants for non-science careers* (12%).

Gender differences regarding children's interest in STEM fields is a growing concern both for academia and the industry [25]. Although there has been progress, women are still underrepresented in STEM areas [26] and especially in the area of computer science [27,28]. The statistics show, for example, that the ratio of women in the IT field is decreasing both in the IT workforce and in IT education, which is detrimental from several perspectives: It is bad for business and poses an equality issue if the shaping of our digital futures becomes a task and duty of men only [29]. Unfortunately, activities involving coding and making have been proven to be highly gendered, and many assumptions, biases, and misbeliefs seem to influence children's participation (e.g. [10,12, 29]).

The gender similarities hypothesis [30] suggests that the apparent differences in motivation, attitudes, and achievement between boys and girls toward STEM subjects are developed over time and are not genetically inherent to their gender. Growing empirical evidence suggests that these differences originate from the socio-cultural features of the learning context [31]. Doerschuk and colleagues [32] found that the gender gap between boys and girls interested in computer science could already be identified at early secondary school age (age ±11). Additionally, a study by Microsoft [33] involving 11,500 girls from 12 European countries suggested that girls' interest toward STEM subjects starts to decrease around age 12, and that it only starts to increase again around age 20 when their career direction has already been determined. The underlying factors for the decreased interest in STEM fields among girls include having no available role model and not getting enough practical, hands-on experience with STEM subjects [33]. Other studies have suggested that females' interest in scientific fields dominated by males is associated with females' self-confidence in their relating abilities, which is significantly supported by early-age possibilities to engage with scientific activities [31]. Thus, engaging girls from early ages with science across informal and non-formal science learning activities might provide the necessary support for developing and sustaining interest toward the STEM fields.

The literature has shown that different adults are vital in shaping and mediating children's, especially girls', STEM experiences (e.g. [34–36]). In informal or non-formal STEM learning settings, facilitators, instructors, mentors, and helpers, among others, have been identified as helping or hindering children's engagement in the activities [34], although thus far it seems that the influence of the gender of these actors has not been scrutinized. In the case of girls, the importance of role models as well as teachers and study counsellors involved in the formal education context has been

Table 1
Differences between formal, non-formal, and informal learning.

Formal	Non-formal	Informal
At formal learning space	Often outside of formal learning environment	Everywhere
Follows a syllabus	Might follow a syllabus	Does not follow a syllabus
Structured	Structured	Unstructured
Compulsory	Usually voluntary	Voluntary
Extrinsic motivation	Typically intrinsic motivation	Intrinsic motivation
Learning goals are predetermined by the educator	Learning goals arise from the learners' conscious decision	No learning purpose in mind
Learning outcomes are measured	No assessment	No assessment

stressed in the literature [35,36]. Previous studies, however, have provided contradictory results on the influence of the gender of the role models or teachers [35,37]. Some studies have argued that female teachers positively affect female students' motivation, confidence, participation, and performance in STEM [37–40], while other studies did not find such a relationship [41] or even reported the opposite [42].

Based on these topics, our study focused on informal and non-formal learning activities by investigating the role of the age and gender of participants and activity leader experts in the goal of the activities, in the covered curricular subjects, and in the place of the activities, together with identified challenges and best practices.

2.1. Research questions

In this study, we set out to answer the following research questions:

(1) *How are the age group and gender of the participants, as well as the experts' gender, related to the covered curricular subjects and to the main goal of the activity?*

(2) *How is the place of the learning activity related to the experts' and the participants' gender, the target age group, the main goal of the activity, and the covered curricular subjects?*

(3) *What are the best practices and the bottlenecks of the investigated activities?*

3. Methods

3.1. Data collection

To address the research questions, we carried out a survey study that targeted highly experienced instructional designers and instructors (i.e., experts) of ongoing informal and non-formal science learning. We followed an intensity sampling approach ("information-rich cases that manifest the phenomenon intensely, but not extremely" ([43] p. 182) and "provides clear examples of the issue in question" ([44] p. 157)), and collected responses from 128 experts from nine European countries (Austria, Finland, Greece, Malta, the Netherlands, Norway, Spain, Sweden, and the UK), each representing a country in which members of the research team are active. Using a survey questionnaire (quantitative approach) that also included open-ended questions (providing qualitative data) gave us the opportunity to collect rich data and in-depth responses that together shed light on the issues investigated in our study [44].

The inclusion criteria for the activities were as follows: (i) to be an informal or non-formal science learning activity, (ii) to be playful, and (iii) to involve either coding or making. The experts were recruited electronically through e-mail or were personally approached and invited to participate in the study. The survey was active in October and November 2018. The study and data collection were approved by the "NSD—The Norwegian Centre for Research Data AS" (the online survey platform was hosted by the Norwegian University of Science and Technology, which was the coordinator of the study). In a specified section, at the beginning of the survey, the respondents were informed about ethical approval, the aim of the project, and the contact persons. They were assured of the confidentiality and anonymity of their responses, especially in the writing of any reports or publications. Lastly, the respondents were informed that their participation was entirely voluntary, and they verified that they were given sufficient information and had given their consent to the handling of their responses for research purposes.

3.2. Development of the survey

In order to design our survey, we first investigated the nature of informal and non-formal science learning activities across the existing literature and established several dimensions. These dimensions are (i) the gender of the experts, (ii) the target audience (age and gender), (iii) the content, (iv) the relation to formal education, (v) the covered curricular subjects, (vi) the main goal of the activity, (vii) the place of the activity, (viii) the best practices, and (ix) the bottlenecks. These dimensions served as the backbone of the survey, which was then developed with questions/statements aimed at assessing these established dimensions. Thereafter, during a pilot exercise, the main structure and content of the survey were discussed and improved in several iterations with a group of experts that consisted of informal and non-formal science learning practitioners and field researchers. The survey consisted of 35 questions, seven of which concerned demographic information. From the remaining 28 questions, which investigated the ongoing activities, 10 were open-ended. The language of the survey was English; however, responses for the open-ended questions could be given in the native languages of the respondents. The final version of the survey was digitized and shared through an online link securing free anonymous access. The dimensions analyzed in this paper, with the related survey items and response categories, are displayed in Table 2.

3.3. Data analysis

Simple frequency analysis was applied for the descriptive statistics. To investigate the effect of age group and gender on the subject areas and goals of the activity, we employed Pearson's chi-squared (χ^2) test, with age group and gender (of both children and instructors) as the three independent variables, and the subject areas and goal of the activity as dependent variables. For the investigation of the associations in relation to the place of the learning activity, Spearman rank order correlation was used. For the quantitative data analysis, the IBM SPSS Statistics v25 software was used.

To answer the research question regarding the best practices and the obstacles, qualitative content analysis [45,46] was applied to the 10 open-ended responses of the survey. This method allowed us to "describe and develop themes from the data" and to "formulate a set of non-overlapping themes" ([47], p. 473). The qualitative software NVivo was used for the analysis, assisting the

Table 2
The investigated dimensions and the related survey items and response categories.

Dimension	Survey item	Predetermined response categories
Experts' gender	Please could you indicate to which gender identity do you most identify?	Male / Female / Prefer not to say
Target audience: Participants' gender	Could you please estimate the percentage of girls/females participating in the activity?	(open-ended question) We coded the responses into the following four categories: less than 45% of the participants are girls (i.e., girls are the minority) / 45%–55% of the participants are girls (i.e., approximate gender balance) / more than 55% of the participants are girls (i.e., girls are the majority) / it depends
Target audience: Participants' age	What age group do you work with during the activity?	4–6 years ("nursery") / 7–12 years ("primary") / 13–17/18 years ("secondary") / 17/18–21 years ("higher education")
Covered curricular subjects	Please indicate which curricular subjects are covered during the activity (if any)	Technology / Computer Science / Mathematics / Physics / Chemistry / Biology / Geography / Humanities / Literature / Art / Design
Main goal	What is the MAIN aim for this activity?	*Awareness*, knowledge or understanding (change in awareness, knowledge, understanding of a particular scientific topic, concept, phenomena, theory, or careers central to the project) / *Engagement* or interest (change in engagement/interest in a particular scientific topic, concept, phenomena, theory, or careers central to the project) / *Attitude* (change in attitude toward a particular scientific topic, concept, phenomena, theory, or careers central to the project or one's capabilities relative to these areas / *Behavior* (change in behavior related to the topic) / *Skills* (Development and/or reinforcement of skills, either entirely new ones or the reinforcement, even practice, of developing skills (e.g., using microscopes or telescopes successfully)
Place of the activity	Where is the learning activity based?	Classrooms, formal learning spaces, etc. / Community labs, FabLabs, etc. / Museums, science centers, outreach centers, libraries, zoos, etc. / Fairs, contests, challenges, etc. / Everyday life (e.g. personal hobbies, gaming, etc.) / In the outdoors
Best practices	In what ways is this activity successful in your opinion? What are its strong points?	(open-ended question)
Bottlenecks	In what ways could this activity be improved in your opinion? What are its weak points?	(open-ended question)

researchers in the development of codes and in the identification of patterns and themes. The themes that emerged were discussed among the main researchers, and agreement was reached. Selected verbatim extracts exemplify the themes identified in each category [48].

4. Results

4.1. Sample descriptives

4.1.1. Demographics of the experts

The response rate per country cross-classified by gender (N = 128) is presented in Table 3. In three of the cases, the country indication was either missing or marked as "other". The gender distribution of males and females was 56.3% and 39.8%, respectively.

4.1.2. Target audience of the activities

As mentioned above, the survey sought to collect data on the target audience of the activities represented in the survey. For this question, respondents were given four options, from which they were allowed to select more than one (see Table 2). Based on the responses, we can conclude that the activities targeted all age groups, but in an uneven distribution. The least targeted age group was the *nursery*-aged pupils (age 4–6; 18%), followed by young adults (*higher education*, age 17/18–21; 25%), *secondary* school students (age 13–17/18; 60.2%), and *primary* school students (age 7–12; 74.2%).

Given the general gender inequality identified in scientific fields (Secion 2.3), we were interested in whether the same tendency could be identified in informal and non-formal environments. Therefore, the survey asked the experts to estimate the average gender proportion of the participants in their activities. For this question, our valid cases were N = 120, since in two cases the experts reported that they did not have any relevant data on girls' participation, and in six cases they did not respond. We coded the responses into the following four categories: (i) *less than 45% of the participants are girls* (i.e., girls are the minority); (ii) *45%–55% of the participants are girls* (i.e., approximate gender balance); (iii) *more than 55% of the participants are girls* (i.e., girls are the majority); and (iv) *it depends*. Out of the 120 participants, 45.8% estimated *less than 45% girls* participate in their activities, 36.7% of the respondents reported approximately *45%–55% girls*, 10.8% reported *more than 55% girls*, and 6.7% responded that *it depends* on various factors. In other words, in roughly one-half of the studied cases, boys were the majority during the activities. However, participation was only dominated by girls in approximately 10% of the studied activities.

4.1.3. Content, covered curricular subjects, and main goal

To explore how the studied informal and non-formal learning activities covered curricular subjects, we provided the respondents with a list of 11 subjects, from which they could choose more than one (see Table 2). Based on the indication of the experts, *technology* (68%), *computer science* (50.8%), *physics* (47.7%),

Table 3
Proportional table of respondents per country by gender (N = 128).

	Female	Male	Prefer not to say/other	Total
Austria	4.7%	7.0%	1.6%	13.3%
Finland	5.5%	9.4%	0.8%	15.6%
Greece	4.7%	4.7%	1.6%	10.9%
Malta	3.1%	2.3%	0.0%	5.5%
Netherlands	1.6%	3.9%	0.0%	5.5%
Norway	3.1%	11.7%	0.0%	14.8%
Spain	7.8%	7.0%	0.0%	14.8%
Sweden	2.3%	3.9%	0.0%	6.3%
UK	5.5%	5.5%	0.0%	10.9%
Missing/other	1.6%	0.8%	0.0%	2.3%
Total	39.8%	56.3%	3.9%	100.0%

mathematics (46.1%), *design* (46.1%), and *arts* (39.1%) are the most favored subjects, followed by *biology* (25.8%), *chemistry* (25%), *geography* (15.6%), *humanities* (14.1%), and *literature* (8.6%).

In order to explore the main goal of the activities, we provided the respondents with five options that were aligned with the framework of the National Science Foundation for evaluating the impact of informal science education projects [49] (see Table 2). In this case, only one option could be selected among the following five: (a) *Attitude*, (b) *Awareness*, (c) *Engagement*, (d) *Skills*, and (e) *Behavior*. The analysis of the responses revealed that the 35.9% of the activities had the goal of increasing *engagement*, 28.3% of increasing *awareness*, 22.7% of improving *skills*, 7% of focusing on *attitude*, and 0.8% on *behavior* change.

4.2. Participants' age, main goal, and covered curricular subjects

Experts could make multiple choices to indicate the age group of their target audience, as they might be addressing different groups in their work (see Table 2). Responses were analyzed to assess whether the participants' age could be related to the goal of the activity and to the covered curricular subjects, with a Pearson's chi-squared test (x^2, N = 128).

With respect to the effect of age on the goal of the activity, no significant association was found for either nursery-aged children (Cramer's V = 0.101, $x^2(5) = 1.295$, p = 0.935), primary-aged children (Cramer's V = 0.170, $x^2(5) = 3.683$, p = 0.596), or secondary-aged children (Cramer's V = 0.164, $x^2(5) = 3.4375$, p = 0.633). However, there was a significant difference between the goal of the activities for young adults (age 17/18–21; Cramer's V = 0.322, $x^2(5) = 13.280$, p = 0.021). Namely, raising *awareness* (Cramer's V = 0.253, $x^2(1) = 8.193$, p = 0.004) was positively and significantly (p < 0.05) associated with this age group. However, *engagement* was found to be negatively associated with young adults (Cramer's V = 0.169, $x^2(1) = 3.665$, p = 0.056).

When assessing the relationship between participants' age and the covered curricular subjects, we found a significant positive association between nursery-aged children and *biology* (Cramer's V = 0.189, $x^2(1) = 4.589$, p = 0.032), a positive association with *chemistry* (Cramer's V = 0.153, $x^2(1) = 2.986$, p = 0.084) and *literature* (Cramer's V = 0.147, $x^2(1) = 2.763$, p = 0.096), and a negative association with *computer science* (Cramer's V = 0.150, $x^2(1) = 2.871$, p = 0.090). Additionally, we found a positive association between young adults (age 17/18–21) and *physics* (Cramer's V = 0.172, $x^2(1) = 3.769$, p = 0.052). Regarding the other age groups (primary and secondary education), no significant association or pattern was found.

4.3. Participants' gender, covered curricular subjects, and main goal

We also examined whether the participants' gender was related to the goal of the activity and to the curricular subjects covered by the activity. As described in Section 4.2, the respondents of the survey were asked to estimate the percentage of girls participating in their activities.

We examined the relationship between these categories and the main goal and covered curricular subject of the activities, as reported by the experts. Here again, chi-squared independence tests were used for examining their association. Regarding the participants' gender in relation to the covered curricular subject of the activity, a statistically significant association was observed for the following subjects: *computer science* (Cramer's V = 0.364, $x^2(3) = 15.88$, p = 0.001), *physics* (Cramer's V = 0.261, $x^2(3) = 8.18$, p = 0.042), *chemistry* (Cramer's V = 0.301, $x^2(3) = 10.88$, p = 0.012), *biology* (Cramer's V = 0.445, $x^2(3) = 23.74$, p = 0.001), and *arts* (Cramer's V = 0.285, $x^2(3) = 9.73$, p = 0.021). In the cases of *arts*, *biology*, *chemistry*, and *physics*, the percentages of boys and girls were mostly equal (45%–55%); while in the case of *computer science*, the percentage of boys participating was in most of the cases higher than the percentage of girls (<45% girls) (Fig. 1).

We found no significant association between the participants' gender and the main goal of the activity. Nevertheless, participation of girls was observed to be lowest in activities where *skills* improvement was reported as the main goal; 63% of the experts who reported *skills* as the main goal of the activity estimated a percentage of less than 45% female participants. The highest participation of girls was reported in the cases where the main goal was *engagement*: 16% of the respondents for this activity goal (*engagement*) also reported a percentage of more than 55% of girls in these activities. Equal representation of girls and boys was reported for activities where the main goal was change in attitude, with 55.6% of the respondents selecting *attitude* as their main activity goal, reporting a percentage of participation of girls between 45% and 55% (Fig. 2).

4.4. Gender of the experts, main goal, and covered curricular subjects

We examined whether a relationship exists between the gender of the experts and the main goal and the covered curricular subjects of the activities (N = 128). For examining the association of the variables, here again, a chi-squared independence test was used, which indicated no significant association between the gender of the experts and the main goal of the activity. In most of the cases, the experts were mainly males, except for the cases where the goal of the activity was *attitude* change. There seemed to be an equal representation of male and female experts when the main goal of the activity was *awareness*, where 47% were male experts, 38% were female experts, and 14.7% were other or preferred not to say. *Behavior* change as the main goal of the activity was selected by one participant, who was female (Fig. 3).

We also found no significant association between the gender of the experts and the covered curricular subject of the activity, except for the case of *biology* (Cramer's V = 0.275, $x^2(3) = 9.66$, p = 0.022), where most of the experts were female (60.6%).
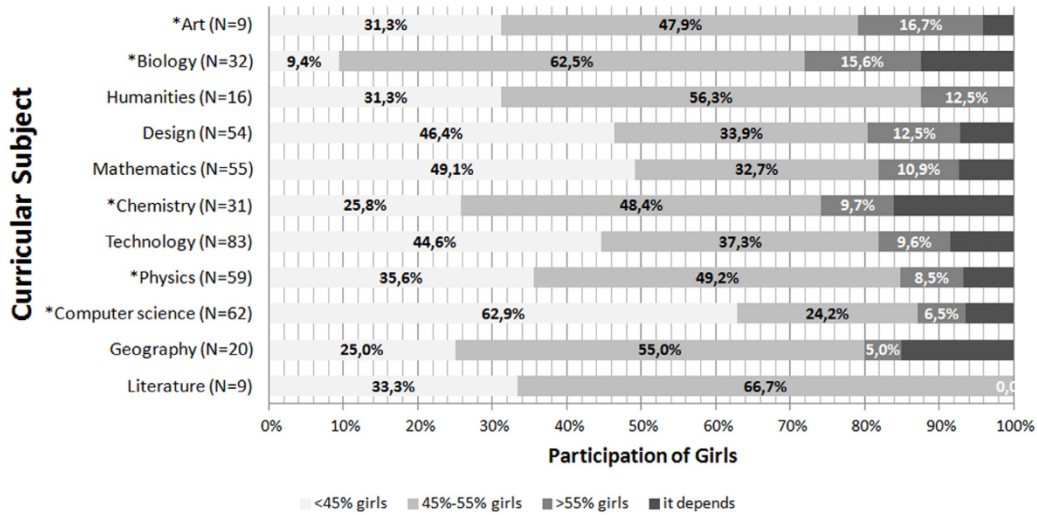
Fig. 1. The interaction between the participants' gender and the covered curricular subjects. * indicates a significant association.
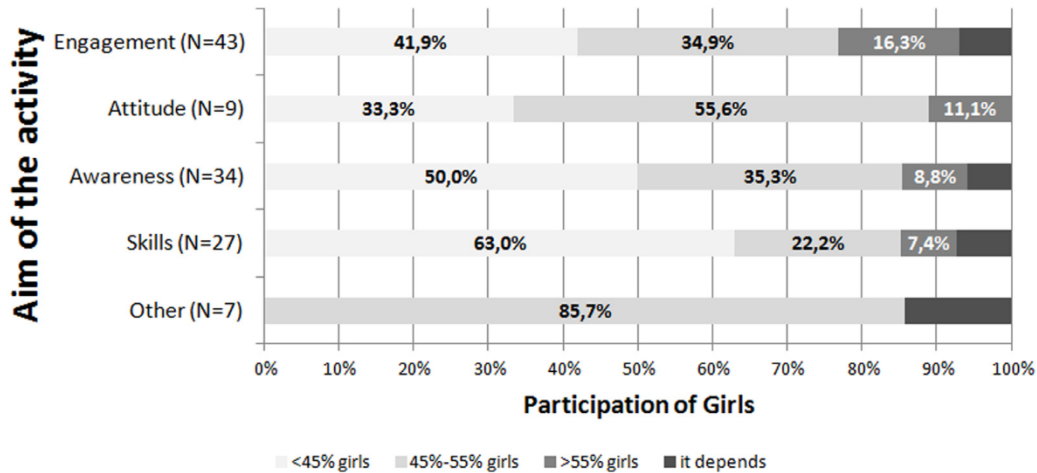

Fig. 2. The interaction between the participants' gender and the main goal of the activity. No significant association was found.
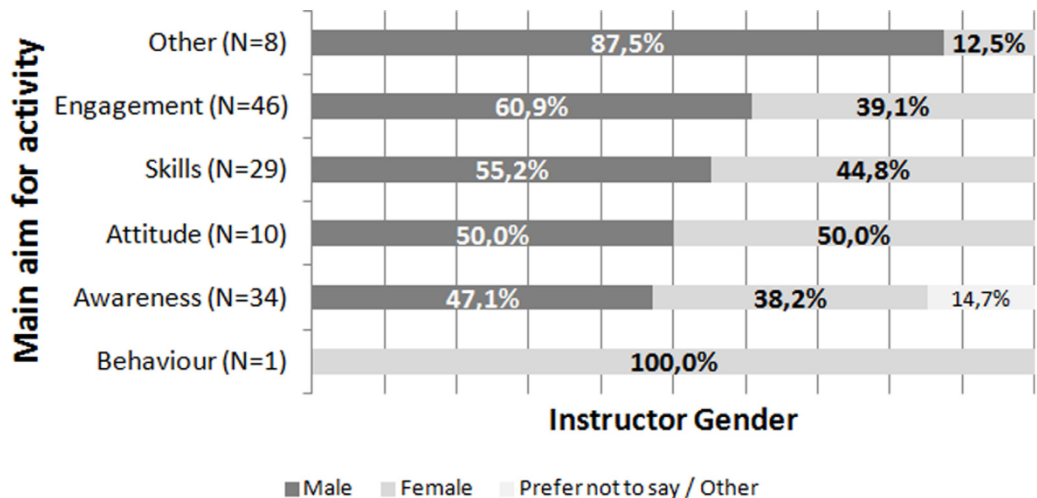

Fig. 3. The distribution of instructors, based on reported gender, among the main goals of the activities.

Also, most of the experts were female in the cases of *chemistry* and *geography*, although with no significant difference. Most of the females in our sample (55%) selected *physics* as the covered curricular subject of their activities, while most of the males selected *technology* (65%) (Fig. 4).

4.5. Place of the activity, target audience, covered curricular subjects, and main goal

For investigating whether the location of the learning activity can be associated with the experts' gender, the target audience (age and gender), the covered curricular subjects, and the main goal of the activity, we applied Spearman's correlation analysis.

The learning activity took place in a *Classroom, formal educational space, etc.* in 42.2% (N = 54) of the investigated practices. Our analysis shows that in this case, *girls' participation* is usually *less than 45%* (r = 0.231, p = 0.009), and the activities are typically not designed for *nursery*-aged children (age 4–6; r = −0.235, p = 0.008); however, they usually cover the formal curricular subject, *computer science* (r = 0.177, p = 0.046), and aim to help the development of participants' *skills* (r = 0.218, p = 0.013).

In 25.8% of the investigated cases (N = 33), the learning activity took place in *Museums, science centers, outreach centers, libraries, zoos, etc.* For these locations, our analysis suggests that, typically, the *activity leaders* are females (r = 0.234, p = 0.009), girls' and boys' participation in these activities is approximately equal (*girls' participation is 45%–55%*) (r = 0.208, p = 0.019), and the activities typically target *nursery*-aged (age 4–6; r = 0.236, p = 0.007) and *primary*-aged (age 7–12; r = 0.225, p = 0.011) children.

When the activity took place in *Community labs, FabLabs, etc.* (N = 15, 11.7%), we found that girls were reported to be typically overrepresented (*girls' participation is >55%*; r = 0.185, p = 0.037).

When the activity took place at *Fairs, contests, challenges, etc.* (N = 5, 3.9%), its typical aim was to *engage* people (r = 0.185, p = 0.036).

Among the investigated activities, only one (0.8%) took place *Outdoors*, during which girls were typically overrepresented (*girls' participation is >55%*; r = 0.323, p = 0.000), and the activity covered the curricular subject *geography*.

Further, three of the investigated activities (2.3%) took place in *Everyday life (e.g., personal hobbies, gaming, etc.)*; however, for this type of activity, our analysis shows no significant correlation between the experts' and the participants' gender, the target age group, the main goal of the activity, and the covered curricular subjects.

An additional 17 respondents (13.3%) indicated *Other* as the place of their activity. Our analysis indicates that for these activities, they typically targeted *nursery-aged children* (age 4–6; r = 0.177, p = 0.046) and covered the curricular subjects *physics* (r = 0.272, p = 0.002), *biology* (r = 0.190, p = 0.031), *humanities* (r = 0.239, p = 0.007), and *literature* (r = 0.209, p = 0.018).

4.6. Best practices

The best practice most emphasized by the practitioners was evoking participants' interest and engaging them in various scientific topics. Different activities must be accomplished with different approaches by, for example, using an especially interesting tool, "Children take an interest in a sometimes difficult topic by learning it through something they find very intriguing (a robot)", applying a specific learning method, "Because of its 'playful' method (making games), it makes the pupils curious and interested, which makes them learn very fast", or taking a novel approach toward a well-known topic (play with ideation cards

to design an intelligent object or create a prototype of a solution to a problem and present it), "It is an approach to coding that does not rely on computers and is quite 'artsy,' thus appealing to people who might not usually be interested in coding". Our general impression is that the surveyed experts were well aware of the importance of interest and engagement, which is nicely summarized in the following response: "I always keep in mind that creating an interest for math, physics, and chemistry in an early age will help the children's future science education, and hopefully they will want to start studying those subjects more".

A closely related best practice is the use of fun, or fun elements, during the activity: "Using games to illustrate certain evolutionary processes or outcomes helps even very young children grasp them. We have had very good feedback from teachers about children's enjoyment and engagement in the workshops".

Another frequently mentioned best practice was accessibility, which can include free access to the activity and the way the topic is introduced: "Even when the scientific topics cover state-of-the-art, advance developments in science and technology, they are communicated in an adapted language which makes them available for a very broad audience".

Further, our experts often reported that a key element of the activity is that it provides participants with the freedom of choice either by the learning approach they take, "This is learner-oriented, and thus the kids really have a say in what they want to do, and we can proceed at the pace suited for the kids", or by using a flexible tool, "Enormous amount of possibilities for projects; using Arduino gives a lot of freedom for the creations".

Another important example of best practices reported by our experts is the support of self-confidence: "Especially for the young minds, a gender-balanced approach will be taken through a multitude of actions, e.g., the choice of the workshop content, how the workshops are organized, and instructions for the coaches. Through these actions, we will bridge specific gender challenges with girls, such as the general tendency for a lack of self-confidence in science and technology, stereotypes about gender roles, and the contextual approach. According to the results of the feedback forms, the developed workshop does have a positive effect of this approach".

Often, an activity builds on several of the aforementioned best practices, which is reflected in the following responses: "Many of our other activities are better at engaging interest and improving people's confidence toward science, since they are not focused on conveying the content of a scientific concept", "The activity is inherently playful, and the end point is clearly ridiculous, which helps present engineering and technology as accessible and approachable, as well as being attractive in its own right", and "The children and families participating learn about the technique 'by accident'; they have a fun day out and do the tests and experiments because they think it is fun, but at the end it is also very educational; and by making education fun, we believe they learn more than in the traditional ways".

4.7. Bottlenecks

While the benefits of coding and making activities have been clearly demonstrated, both in the literature and in the experiences of participants, significant challenges also accompany such activities. Our experts identified constraints in resources (i.e., facilitators, materials, space), funding, time, content of activities, and sustained collaboration with parents and other community actors.

Limited financial support was mentioned frequently by the experts, who reported that "our growth depends on the funding. Every year, we need to do fundraising, and this uncertainty is the main weakness of the project". Having a limited budget or
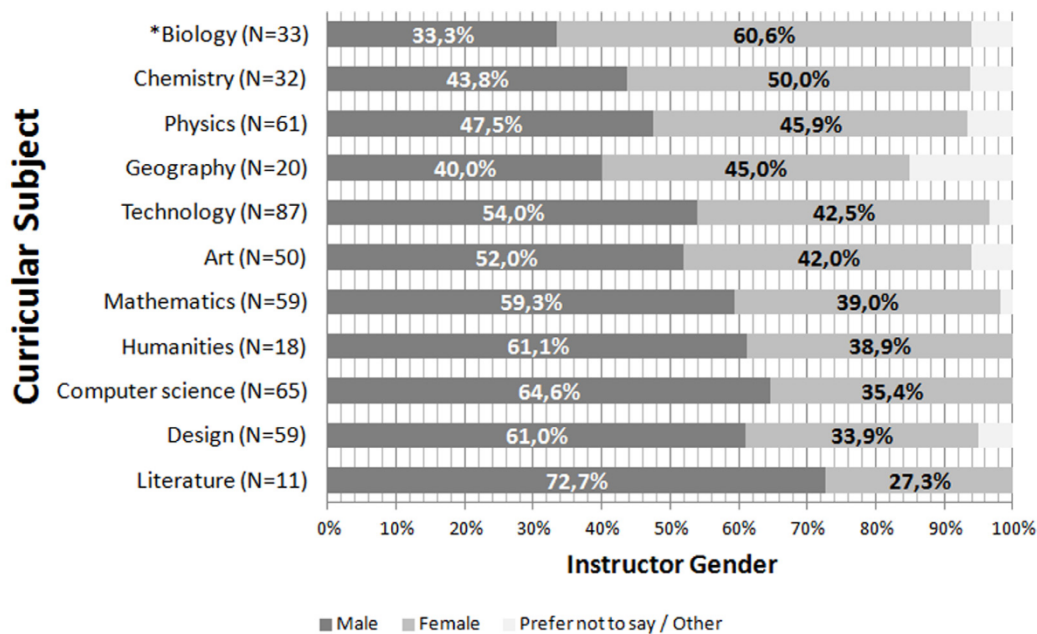
Fig. 4. The interaction between the activity leader experts' gender and the covered curricular subjects. * indicates a significant association.

no budget at all influences the delivery and frequency of these activities and thus disrupts continuity and the creation of a community around these activities. It also poses restrictions on the number of staff members involved in the activities and the range of materials used in them, especially due to the changing nature of the technology (i.e., robots). Another factor influencing the quality of organizing and running such activities is limited time. Several of the experts mentioned that they needed more time in order to run such activities. The temporality of such activities also became very evident as a shortcoming, as these activities tend to be organized on a less regular basis. The interconnectedness of time, space, and budget is very well articulated in the following response: "A weak point is the continuity of activities. It is a personal project that tries to become a profession, but due to the low demand for different reasons, it is not possible to avail as quickly as I would like. There are ideas and sketches of new workshops, but it is necessary to invest more time and money in their design and development, to build new materials and create plot threads".

Similarly, having a limited target group of participants has also been raised as an issue. Lack of diversity in the participants' age and cultural and socioeconomic backgrounds has also been named as one of the aspects that affect the quality of the activities included in our survey. At the same time, having a diverse audience with various degrees of previous knowledge and skills makes it difficult for the practitioners to coordinate and address such diversity during short sessions. Making and coding workshops involve participants of different ages and levels of experience who work with diverse media, resources, and technologies [50]. As articulated by one of the experts: "The group is usually a mix of different types of people; some know lots of programming, while others do not. A classroom full of like-minded individuals would be the best". Although commonly identified in the classroom setting as well, diversity in the levels of expertise of the participants in making and coding activities is much more difficult to address, as the practitioner often has not met these participants before. The lack of continuity of these activities, and their voluntary nature, appears to have an impact on how the practitioner can adjust the workshop/activity to address those who are less or more experienced.

To address the different levels of expertise of the participants, a few experts have mentioned the need to offer diverse content in the activities. These experts suggested that having more high-quality games, renewing activities on a regular basis, and including staff members with different skills and background in coding can advance such diversity. By including different levels of difficulty in the activities offered, experts might be able to sustain the participants' engagement longer.

It is also noteworthy that a number of experts referred to the wider structure/framework in which coding activities are organized as problematic. For example, one mentioned that "STEM activities require a stable educational framework for implementation", while another stated that "Technology education should be included in basic education as a *technology* subject [in my country]". These two excerpts point to the main differences between formal and informal/non-formal activities as well as to the stability and continuity characterizing formal education. Furthermore, not having staff and practitioners with a formal background in pedagogy emerged as an obstacle with respect to running such activities.

5. Discussion

Our results from the aforementioned nine European countries illustrate how the currently ongoing informal and non-formal science learning activities have a vivid and broad range of variety in terms of their main goal, covered curricular subjects, target audience, and place of the activity.

Regarding the goal of the activity and the gender of the experts, no significant relationship was found. It is important to note that male experts were overrepresented in our sample, except in the case where the main goal of the activity was *attitude* change. This may be studied further to understand whether this is a general tendency or whether it is due to sampling bias. Concerning outreach learning activities, in their study, Vennix et al. [51] found that in the group of guides and teachers of the activities, males were overrepresented, which might have affected students' views about the STEM field. In the same study, the guides had a STEM background, acted as role models, and made contributions that were thought of as valuable.

With regard to the covered curricular subjects and to the activity leader experts, a significant association was found between females and *biology*, and the majority of the experts of activities covering *chemistry* and *geography* were also females. Additionally, the most commonly covered subject by male experts was *technology*, while the most commonly covered curricular subject among females was *physics*. These results are also in accordance with the aforementioned US study [52], with particular reference to the significant association between women and *biology*. Our findings lend support to the notion that this phenomenon has its roots in early childhood, as *biology* was found to be significantly related to nursery-aged children, while an approximately equal number of girls and boys were found to be present overall in the activities that covered the subject. Concerning the context of outreach learning activities, in cases where emphasis was placed on society or on a community-based context, there was statistically significant higher autonomy and cohesiveness perceptions [51].

Given that the covered curricular subjects and the main goal of the activity were also related to the participants' age and gender, we propose that there is an indirect relationship between the activity leaders' and children's gender, and possibly also an influence of the former on the latter. Thus far, this relationship has received less attention in the literature, even though various kinds of actors and their diverse kinds of influences on children's learning experiences have been reported (e.g. [34]). Further research is needed to understand the role that the gender of these adult actors plays in this context. We acknowledge that, currently, contradictory results have been generated about the influence of the gender of role models and teachers on girls' motivation, confidence, participation, and performance in STEM [35]. Ensuring that approximately 40% of the experts are female can provide girls with the much needed role model pointed out by the Microsoft study [33]. We maintain that regardless of their gender, these adult actors certainly act as important role models and educators for children, and therefore further research is definitely needed to scrutinize and appreciate the influence of these actors.

The main target age group of the activities led by the surveyed experts is either primary school (7–12 years) and/or secondary school (13–17/18 years) students—a finding that agrees with those reported by Falk and colleagues [2]. Our research results differ in the sense that we found very limited coverage for nursery-aged children (age 4–6), while the coverage for young adults (age 17/18–21) was moderate. Our findings suggest that girls were generally underrepresented in the surveyed activities. In approximately one-half of the cases, boys were estimated as the majority, compared to 10% for girls. However, about one-third of the investigated activities were gender-balanced. In their literature review on the maker movement, Papavlasopoulou et al. [19] investigated a subject area in which a making approach was implemented, and most of the included papers aimed to improve participants' programming skills and computational thinking. In addition, most studies were targeted to children up to the age of 14; fewer studies targeted children over 14 years old, and only one study, which took place in a museum, included participants with a wide range of ages (from the age of 6).

Highlighting the link between formal and informal/non-formal learning, the majority of the studied activities covered the formal educational subjects of *technology*, *computer science*, *physics*, and *mathematics*. Based on the responses, we can conclude that the main goals of these activities are to increase *engagement* and *awareness* and to improve *skills*—a finding that aligns with the goals reported by Falk and colleagues [2]. The general goal of the activities was to playfully encourage young people to become interested and engaged in scientific topics, and to improve their related skills.

Regarding the participants' gender, we can conclude that gender is related to both the goal and the covered curricular subjects of the activities. As for the goal of the activities, participation of girls was lowest in activities in which the goal was *skills* improvement, and highest in activities in which the main goal was to increase *engagement* with scientific topics. A possible explanation for this finding could be that some of these activities aim to encourage higher participation of women in STEM-related education. Studies have shown that the prevailing stereotype of the male computer scientist prevents women from being more interested in joining this profession. Therefore, different efforts and activities specifically designed for girls have been developed to attract them to computer science. These efforts complement programming environments like LiliPad Arduino [53], which focuses on girls. Most of the time, the aim is to increase girls' interest in coding and to cultivate positive attitudes among them [54,55]. In her study, Robertson [55] showed that after a game development project with students, boys' enjoyment was higher than that of girls. With respect to the covered curricular subjects, we found that when *arts*, *biology*, *chemistry*, and *physics* were covered, the gender distribution of the participants was approximately equal. However, in the case of *computer science*, boys were overrepresented. These results are in accordance with data collected about STEM education and degrees in the US [52], especially with regard to *biology*, which is known to be the only gender-balanced STEM field. Walan [56] examined the potential of activities in a makerspace combined with drama for young girls. The results showed that interest in science and technology as well as twenty-first-century skills regarding creativity, problem-solving, and cooperation were advanced in some young girls.

Further, we found that the location of the activity can also be associated with the target age group, the gender of the expert and of the participating children, the main goal of the activity, and the covered curricular subjects. We suggest further investigation into whether our findings reflect general tendencies or are due to sampling bias. Regarding the age group, we found that nursery-aged children (age 4–6) and primary school-aged children (age 7–12) are typically targeted by activities that take place at *Museums, science centers, outreach centers, libraries, zoos, etc.*, but that nursery-aged children are not targeted by activities that take place in *Classrooms, formal educational spaces, etc.* Regarding the gender of the expert, we found that at *Museums, science centers, outreach centers, libraries, zoos, etc.*, women usually lead the activities. Concerning the gender distribution of the participating children, we found that in the *classroom-based* activities, girls are generally underrepresented, while boys' and girls' participation is reported to be approximately equal in *museum-based* activities; however, girls are usually overrepresented in *community lab-based* and *outdoors-based* activities. As for the main goal of the activity, *classroom-based* activities were found to have the objective of skills improvement, and *fair or contest-based* activities were aimed at engaging the participants.

We identified the best practices of the surveyed activities across the open-ended question responses of the experts. We conclude that evoking participant interest and engagement is the most frequently mentioned best practice. This is in line with previous research [54,55] that described aspirations to increase girls' interest in STEM fields, but it is also complementary in that we introduced hands-on tips to fulfill this aim: by using an especially interesting tool (e.g., a robot), a specific learning method, or a novel approach to the introduction of a well-known topic. Further, adding fun elements, making the activity accessible for a wide audience, providing participants with the freedom of choice, and supporting their self-confidence emerged as the key components of the surveyed activities. Some of the experts reported on applying a combination of these best practices—for example, making an activity playful also makes the topic more accessible.

Besides best practices, our experts' comments identified bottlenecks, mainly constraints in resources (i.e., facilitators, materials, space), funding, time, content of activities, and the formal education of the practitioners. One possible solution to overcome these challenges is better financial support at both the national and European level. As an increasing number of studies are pointing out the importance of these activities for children's interest in STEM education, it is also becoming increasingly common to provide children with a stable background. Further, we identified obstacles in the wider structure in which the activities are organized. Being, for example, not part of the official curriculum has been identified as one of the reasons why these activities cannot reach their full potential. Accordingly, better and to some extent more formal or regulated collaboration between the formal, informal, and non-formal learning places, as well as the acknowledgment of each other's contributions to children's science education, would be beneficial for all parties. This was also pointed out in previous research [57] on Australian best practices for promoting the participation of young people in STEM. Namely, it was found that the key components of a successful STEM strategy are (i) coordinated collaboration between stakeholders across the STEM ecosystem, (ii) a shared vision, priorities, and common language around STEM, (iii) sustainable inclusive education and engagement for all STEM fields, (iv) curricular implementation, and (v) sustained professional development. Our research findings, despite originating from informal and non-formal science learning activities, also support these components.

Evaluating our research findings, it can be concluded that the activities studied in our research contribute to stimulating young Europeans' interest toward scientific topics. The studied activities are mainly intended to be playful and engaging—at the affective, behavioral, and cognitive levels, these activities are aimed at triggering young people's curiosity and intrinsic motivation in order to enhance their willingness to learn about science. Although girls were generally underrepresented in the activities investigated in our study, our findings are promising, as we found an approximate gender balance in more than one-third of the activities.

6. Limitations and future work

We caution that this study reflects only a snapshot of a potentially dynamic context, and thus our findings may not remain valid in the future. As we applied an intensity sampling method, the generalizability of our results is also slightly limited. Therefore, studying the patterns revealed here with a wider sample would add to our knowledge on this matter. Additionally, as we indicated already, subsequent research is required to address whether males are generally overrepresented as informal and non-formal science learning experts, or whether this is due to sampling bias.

Nonetheless, this study can serve as a basis for comparison for future research. The tendencies identified here might be used as indications for determining the need for supplementing activities or adjusting existing ones, e.g., increasing girls' involvement or designing activities that better suit the anticipated audience. However, it is important to note that given the nature of the study, the directions of the revealed relationships cannot be determined; hence, they should be investigated further.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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